Seed yield and quality from early cone collections in Newfoundland populations of black spruce and white spruce

A. Mosseler and P. Thoss
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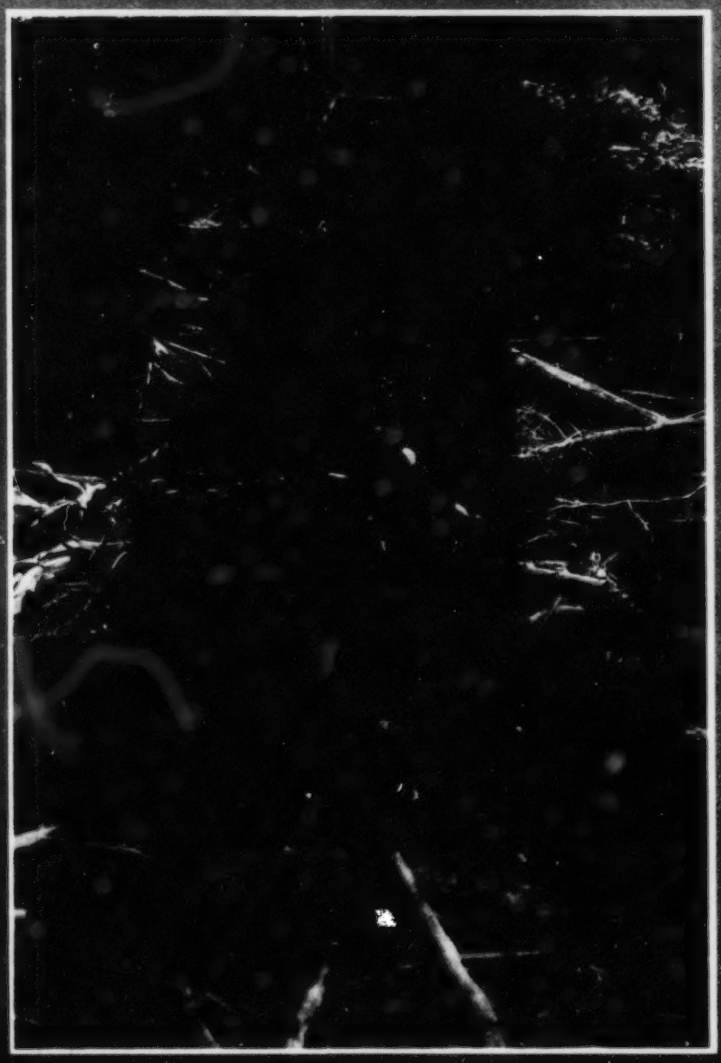

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SEED YIELD AND QUALITY FROM EARLY CONE COLLECTIONS IN NEWFOUNDLAND POPULATIONS OF BLACK SPRUCE AND WHITE SPRUCE

by

A. Mosseler and P. Tricco

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ABSTRACT

Seed shortages in coniferous tree species often limit artificial forest regeneration efforts and silvicultural options such as direct seeding. Accumulated growing degree-days (GDD) were used to predict the earliest time at which cones of black spruce and white spruce could be collected without adversely affecting seed yield and quality. Cones were harvested at intervals of 100 GDD beginning at about 600 GDD after pollination and ending with natural seed release in white spruce at between 1200 and 1250 GDD. In black spruce, the number of full seeds per cone and seed size increased significantly between 800 and 900 GDD and stabilized thereafter. However, seed viability did not change significantly in seeds from black spruce cones collected after 800 GDD. No significant differences occurred in number of full seeds per cone or seed size in white spruce seeds extracted from cones harvested after 900 GDD, although important reductions in white spruce seedling survival occurred in seeds extracted from cones collected prior to the accumulation of 1100 GDD. Cones from black spruce can be collected as early as 900 GDD, and white spruce as early as 1100 GDD without significant losses in seed yield or quality. Information is provided on the application of growing degree days as a physical index for monitoring seed maturation in Newfoundland for the purpose of maximizing the cone harvesting period in black spruce and white spruce.

RÉSUMÉ

Les pénuries de graines chez certaines espèces de conifères limitent souvent les efforts de reforestation et les options de syviculture comme le semis direct. L'accumulation des degrés-jours de croissance (DJC) a été utilisée pour prédire le moment le plus propice pour recueillir les cônes d'épinette noire et d'épinette blanche sans nuire au rendement et à la qualité des graines. Des cônes ont été récoltés par intervalles de 100 DJC, à partir d'environ 600 DJC jusqu'au moment de la chute naturelle des graines de l'épinette blanche, soit entre 1 200 et 1 250 DJC. Chez l'épinette noire, le nombre de graines pleines par cône et la grosseur de ces graines commence à augmenter de façon notable entre 800 et 900 DJC, pour se stabiliser par la suite; mais la viabilité des graines de l'épinette noire ne varie pas de façon significative dans les cônes recueillis à partir de 800 DJC. Chez l'épinette blanche, on n'a observé aucune différence notable dans le nombre de graines pleines par cône ou la grosseur des graines extraites des cônes après 900 DJC; on a toutefois observé d'importantes réductions du taux de survie des semis d'épinette blanche provenant des graines dont les cônes avaient accumulé moins de 1 100 DJC. Les cônes d'épinette noire peuvent donc être récoltés dès les 900 DJC et ceux d'épinette blanche, après 1 100 DJC, sans perte significative de rendement ou de qualité des graines. Des renseignements sont fournis sur l'application des degrés-jours de croissance comme indicateur physique de surveillance de la maturation des graines à Terre-Neuve, dans le but de tirer un profit optimal de la période de récolte des graines d'épinette noire et d'épinette blanche.

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SEED YIELD AND QUALITY FROM EARLY CONE COLLECTIONS IN NEWFOUNDLAND POPULATIONS OF BLACK SPRUCE AND WHITE SPRUCE

by

A. Mosseler and P. Tricco

INTRODUCTION

Cone crops in many conifers are sporadic and seed shortages have hampered artificial forest regeneration efforts, particularly when large amounts of seed are required for low cost silvicultural treatments like direct seeding. Sporadic cone crops (Zasada, 1973), rapid seed dispersal upon cone maturation, (Cram and Worden, 1957) and cone and seed predation (West, 1989; Mosseler and Tricco, 1991) make it necessary to take full advantage of abundant cone crops in white spruce, *Picea glauca* (Moench) Voss., and black spruce, *P. mariana* (Mill.) B.S.P.

Newfoundland's artificial regeneration program is based largely on the planting of black spruce and white spruce. However, seed collection from native populations has been adversely affected by severe insect infestations over the past 20 years (Schooley, 1980; Hall, 1981). This has forced Newfoundland's Department of Forestry and Agriculture to import seed from untested mainland seed sources. An extension of the season for cone collection would permit more seed to be collected from well-adapted local populations in years that provide an abundant cone crop, and would facilitate planning for operational cone collection.

Early cone collections are possible in many conifers but methods for monitoring seed ripeness are generally inadequate (Edwards, 1980). Proposed physical indices of cone maturity have been either too subjective and unreliable, or have required laboratory assessments that are impractical for operational seed collection (Crossley, 1953; Cram and Worden, 1957; Zasada, 1973; Fechner, 1974; Winston and Haddon, 1981). An efficient and economical method for predicting seed ripeness in conifers could involve the use of easily monitored climatic indices such as cumulative growing degree days. Growing degree days (GDD) are the degrees of temperature above 5°C for each day that the daily mean temperature exceeds a 5°C threshold (Atmospheric Environment Service, 1984). GDD provide a reference system for relating the stages of development in plants to the daily thermal regime (Mosseler and Papadopol, 1989). However, quantitative predictions of seed ripeness based on this index have received little attention (Edwards, 1980).

When properly stored under ventilated, ambient conditions, the cones of many conifers can be collected prior to their natural ripening dates without important losses in seed yield and quality (Crossley, 1953; Rediske, 1969; Zasada, 1973; Fechner, 1974; Winston and Haddon, 1981). However, the optimum conditions for early cone collection have not been well defined (Zasada, 1973; Edwards, 1980; Haddon and Winston, 1981). The use of GDD to guide the seasonal timing of cone collections, together with natural after-ripening under cool, ventilated conditions may permit early cone collection without reducing seed yield or seedling quality (Zasada, 1973). A preliminary study

on spruce cone maturation was conducted by Curran *et al.* (1987). Our objectives were to define the minimum GDD requirements for cone collection in black spruce and white spruce, and to identify species variation in cone and seed maturation.

MATERIALS AND METHODS

Cone collections were made at intervals of approximately 100 GDD in 1988 from 6 natural stands of white spruce and black spruce (Figure 1). Cones were collected from 4 trees -ranging in age from 40 to 70 years- from each species, at each of 6 locations across central Newfoundland beginning at approximately 600 GDD after pollination, and ending at approximately 1200 accumulated GDD. Accumulated GDD were based on the simple mean of the maximum and minimum daily temperatures recorded at the Atmospheric Environment Services (Environment Canada) weather station nearest to each site (Figure 2). Longer term averages for GDD accumulations for locations across insular Newfoundland have been compiled in Appendix 1, for the period from 1976 to 1990, from information in the Atmospheric Environment Services weather data bank.

A minimum of 4 samples of 10 cones per tree were collected at random throughout the upper tree crown on each harvesting date. Cones were stored in a ventilated shed at the Wooddale Provincial Tree Nursery for after-ripening under ambient conditions until 1300 GDD had accumulated. Cones were then dried at ambient temperatures for several more weeks as seed extraction proceeded. Cones of white spruce released their seeds naturally upon drying. However, the serotinous cones of black spruce were dried at 50°C for 24 hours, before seed extraction. The cones were then subjected to a second seed extraction cycle in which cones were soaked for 1 hour in water prior to drying at 50°C for 24 hours followed by seed extraction. The following data were recorded for each 10 cone sample: (i) fresh weight of cones following harvest, (ii) oven dry weight of cones following seed extraction; (iii) total number of seeds per cone sample, (iv) number of full seeds per cone sample; and (v) weight of the full seeds. Seeds were counted with an electronic counter and were judged full if they sank in 95% ethanol. Full seeds were weighed to the nearest 0.0001 g, and the weight per 1000 seeds was calculated. Cones were weighed to the nearest 0.01 g following drying at 105°C for 24h.

A single, full seed was deposited in each cell of a commercial nursery tray (45 seedling-cells per tray). Seed viability from early cone collections was then evaluated as seedling survival at 6 weeks of age. ANOVA of the number of seedlings surviving at 6 weeks of age was based on 4 replicates of 45 seedlings per tree ($n = 24$ trees per species) for each cone harvesting date. Data for cone and seed traits and for seedling survival were analysed by ANOVA (Mosseler, 1992). Following 4 months of growth under glasshouse conditions seedlings were transplanted to the field to monitor growth performance under natural conditions, and results from this aspect of the work will be reported at a later date.

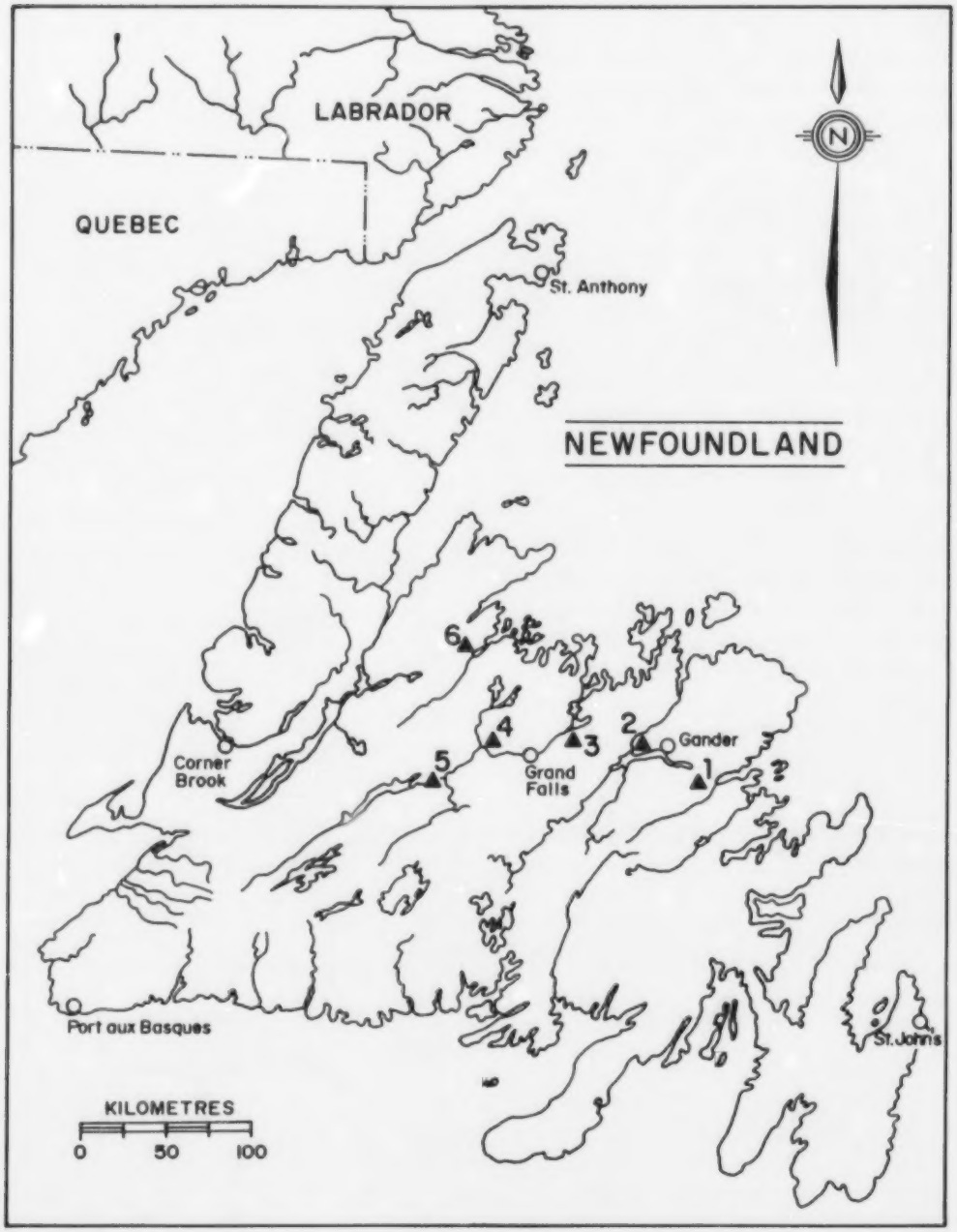

Figure 1. Collection sites of black spruce and white spruce cones in Newfoundland, Canada, at 100 growing degree-day intervals in 1988 (1 Gambo, 2 Glenwood, 3 Norris Arm, 4 Grand Falls, 5 Millertown Junction, and 6 Springdale).

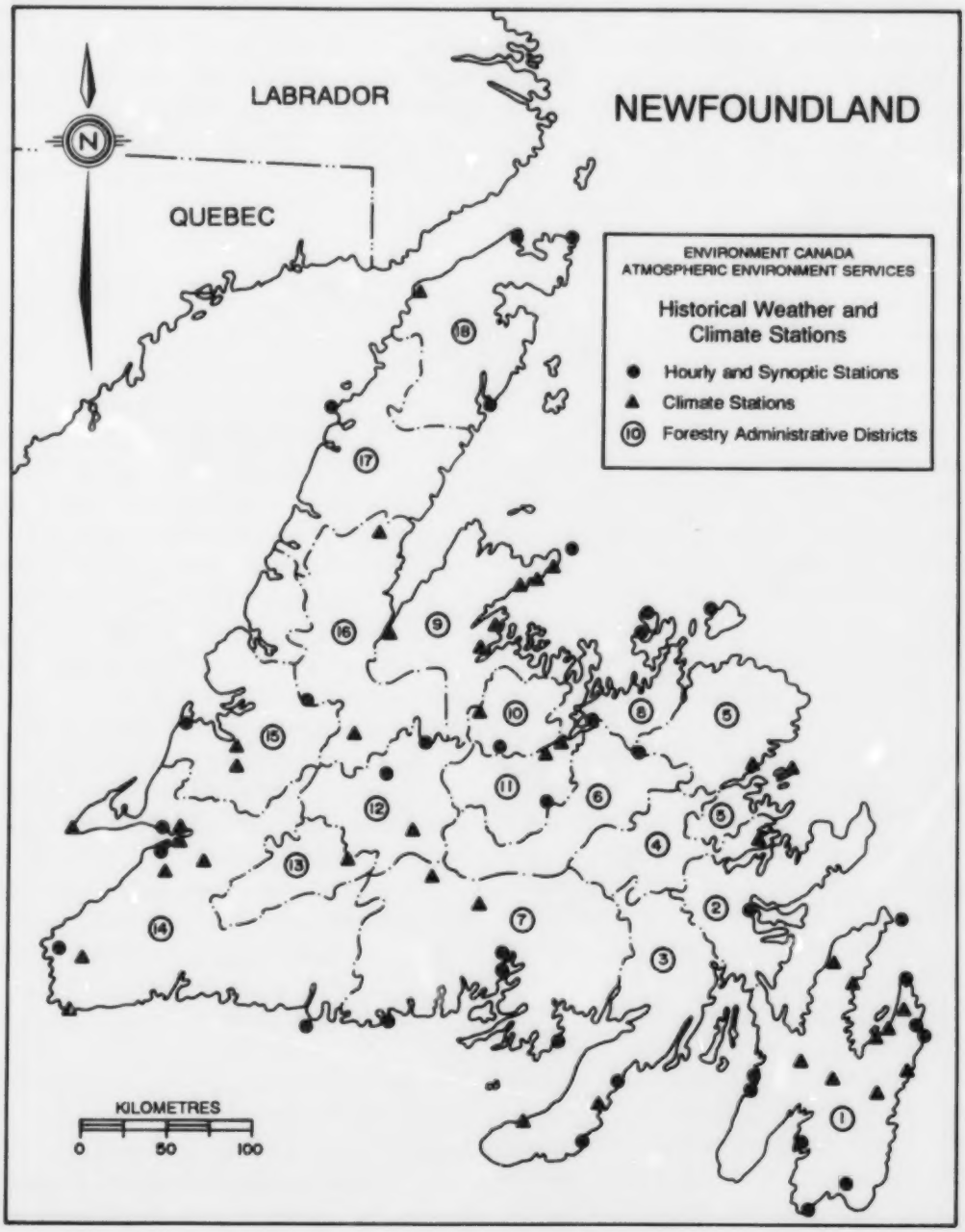

Figure 2. Atmospheric Environment Service (Environment Canada) weather stations and Department of Forestry and Agriculture forestry unit offices in Newfoundland.

RESULTS AND DISCUSSION

Very little of the variation in seed yield, seed quality and seed viability within black spruce or white spruce was attributed to differences among natural populations. However, variation in cone and seed traits among individual trees within a population was highly significant. These results correspond with general trends established for the distribution of genetic variation in outcrossed conifers (Hamrick and Godt, 1990).

Growing degree-day accumulations at the time of cone harvest from about 800 GDD onwards are presented in Table 1. Cones collected prior to the accumulation of 800 GDD yielded few viable seeds and were excluded from ANOVA. The average number of full seeds per cone, and the weight of 1000 seeds in black spruce did not change significantly after about 900 GDD (Table 2). The average number of empty seeds per cone was negatively correlated with the number of full seeds per cone, and there were no significant differences in the ratio of empty to full seeds per cone in black spruce following the accumulation of 900 GDD. Cone dry weight did not change significantly after about 800 GDD, indicating that cones had fully developed by that time. However, cone green weight declined significantly after approximately 1100 GDD as cones ripened. Similar decreases in cone moisture have been associated with natural cone ripening in conifers (Cram and Worden, 1957; Zasada, 1973). Some significant differences in seedling survival were observed in the glasshouse in seed from cones collected between 800 and 900 GDD but these differences (about 16%) may not be important when compared with gains obtained from predator avoidance through early cone collection in black spruce (West, 1989).

Table 1. Growing degree-days accumulated in Newfoundland in 1988 on the date of cone harvest for black spruce and white spruce (see Figure 1 for stand locations).

	Accumulated Growing Degree-Days (GDD)				
Population	**Date 1**	**Date 2**	**Date 3**	**Date 4**	**Date 5**
Gambo (1)	809.2	896.2	992.8	1145.8	1256.0
Glenwood (2)[1]	792.9	879.2	1017.2	1110.3	-
Norris Arm (2)[2]	792.9	879.2	1017.2	1110.3	-
Aspen Brook (4)[2]	767.7	883.0	954.6	1097.5	1214.2
Exploits Dam (5)[2]	767.7	883.0	954.6	1097.5	1214.2
Springdale (6)	765.7	844.7	973.9	1065.1	-
Mean (GDD)	782.7	877.6	985.0	1104.4	1228.1

[1] GDD data from Gander Airport
[2] GDD data from Grand Falls

Table 2. Average cone and seed traits for black spruce cones collected in Newfoundland in 1988 on 5 separate occasions at 100 growing degree-day intervals (mean ± S.E.; n = 24 trees/species/cone harvest date).

Cone and Seed Traits	Average Growing Degree Days Accumulated by Cone Harvest Date				
	782.7	877.6	985.0	1104.4	1228.1
No. of full seeds/cone	13.1 ± 1.6b[1]	28.1 ± 1.2a	29.8 ± 1.3a	31.4 ± 1.3a	29.5 ± 2.2a
No. of empty seeds/cone	24.0 ± 1.4a	15.7 ± 0.7b	15.0 ± 0.7b	16.2 ± 0.6b	15.4 ± 0.9b
Ratio of empty to full seeds/cone[2]	10.2 ± 1.5a	0.67 ± 0.06b	0.56 ± 0.03b	0.57 ± 0.03b	0.63 ± 0.05b
Weight of 1000 full seeds (g)	0.984 ± 0.021b	1.183 ± 0.019a	1.239 ± 0.020a	1.273 ± 0.022a	1.225 ± 0.030a
Cone dry weight (g)	1.36 ± 0.03 a,b	1.44 ± 0.03a,b	1.48 ± 0.03a	1.41 ± 0.03a,b	1.33 ± 0.04b
Cone green weight (g)	3.44 ± 0.08a	3.52 ± 0.08a	3.50 ± 0.08a	3.23 ± 0.09a	2.67 ± 0.10b
Seedling survival[2,3]	28.2 ± 1.5b,c	24.4 ± 1.0c	29.6 ± 0.7a,b	33.4 ±0.6a	32.1 ± 0.6a,b

[1] Letters following numbers indicate significant differences at $p < 0.05$.

[2] Data on the ratio of empty: full seeds/cone and seedling survival (at 6 weeks of age) in white spruce were not normally distributed and could not be subjected to ANOVA.

[3] Number of seedlings surviving at 6 weeks of age (n = 45 full seeds).

However, losses in seed number (about 127%) and seed weight (about 25%) were significant in black spruce cones collected prior to 900 GDD (Table 2).

The average number of full seeds per cone and seed size increased steadily in white spruce from 800 to 1100 GDD, but significant differences were not observed after 900 GDD (Table 3). Nevertheless, small differences in seed size may be important for subsequent seedling growth performance because larger seeds tend to produce larger seedlings in white spruce (Khalil, 1981, 1985), and in many other tree species (Spurr, 1944; Hough, 1952; Harper *et al* 1970; Dunlap and Barnett, 1983). However, under the artificial conditions of containerized, glasshouse propagation of tree seedlings, differences in seedling growth performance related to seed size may not be as important as under highly competitive conditions in nature.

Significant reductions in seed viability from cone collections prior to 1100 GDD (Table 3) suggest that white spruce seed may be undergoing important physiological changes following the attainment of maximum seed size, and that these changes may continue until the beginning of natural seedfall (Zasada, 1973). This provides a very short time period of approximately 100 GDD for early cone collections of white spruce (or 1-2 weeks depending on GDD accumulation rate late in the growing season).

White spruce cones attained their maximum size by 800 GDD. A significant reduction in moisture content occurred in freshly harvested cones from 1100-1200 GDD as they ripened (Table 3). Changes in cone moisture content have been used to signal cone maturation in white spruce, and have been suggested as a useful indicator for early cone collection (Cram and Worden, 1957). However, changes in moisture content occurred gradually after about 1000 GDD and were not precisely related to seed ripeness (Table 3). Significant reductions in seed yield, seed size and seedling survival occurred in white spruce cones collected prior to 1100 GDD, whereas cone moisture content did not decline significantly until between 1100 and 1200 GDD.

The significance of differences in the ratio of empty to full seeds per cone, and in seedling survival in white spruce were not assessed by ANOVA due to deviations from normality in the distribution of data. Nevertheless, the trends in these parameters are evident (Table 3). The results presented here are at variance with those reported by Curran *et al.* (1987) from a preliminary investigation of cone maturation that suggested white spruce cones ripened earlier than black spruce cones.

Black spruce cones can be harvested as early as 800 GDD after pollination without significant loss in seed viability, but seed yields may be significantly reduced in cones collected prior to 900 GDD. Longer term (up to 14 year) averages for GDD accumulations compiled at 5 day intervals for locations across insular Newfoundland (Appendix 1) suggest that black spruce cone collections in the vicinities of Stephenville, Deer Lake, Lewisporte, Buchans, Gander and in the interior of Terra Nova National Park could begin around August 20; in the vicinities of Corner Brook, Grand Falls, Wooddale, Botwood, Norris Arm, and Lethbridge, black spruce cone collections could begin between August 10 to 15. In coastal areas, around Sop's Arm and Springdale black spruce cone collection may have to be delayed until early September. However, it is important to

Table 3. **Average cone and seed traits for white spruce cones collected in Newfoundland in 1988 on 5 separate occasions at 100 growing degree-day intervals (mean ± S.E.; n = 24 trees/species/cone harvest date).**

Cone and Seed Traits	Average Growing Degree Days Accumulated by Cone Harvest Date				
	782.7	877.6	985.0	1104.4	1228.1
No. of full seeds/cone	7.4 ± 1.8c[1]	15.0 ± 1.1b	18.3 ± 1.0a,b	21.5 ± 1.0a	17.4 ± 1.2a,b
No. of empty seeds/cone	54.0 ± 1.9a	45.8 ± 1.7b	44.2 ± 1.2 b	46.0 ± 1.2b	54.3 ± 1.3b
Ratio of empty to full seeds/cone[2]	99.7 ± 21.3	28.5 ± 10.2	3.4 ± 0.2	2.9 ± 0.05	3.0 ± 0.06
Weight of 1000 full seeds (g)	2.114 ± 0.074c	2.591 ± 0.0	2.828 ± 0.04a,b	2.984 ± 0.047a,b	3.030 ± 0.058a
Cone dry weight (g)	0.87 ± 0.02a	0.91 ± 0.02a	0.95 ± 0.02a	0.93 ± 0.02a	0.93 ± 0.03a
Cone green weight (g)	2.93 ± 0.06a	2.93 ± 0.06a	2.91 ± 0.06a	2.64 ± 0.07a	2.26 ± 0.09b
Seedling survival[2,3]	3.2 ± 0.7	6.3 ± 0.9	12.1 ± 1.2	24.7 ± 0.8	25.5 ± 0.9

1 Letters following numbers indicate significant differences at $p < 0.05$.

2 Data on the ratio of empty:full seeds/cone and seedling survival (at 6 weeks of age) in white spruce were not normally distributed and could not be subjected to ANOVA.

3 Number of seedlings surviving at 6 weeks of age (n = 45 full seeds).

remember that considerable annual variation can occur around these average dates at any location (Appendix 1). Therefore accurate GDD summaries must be obtained for specific areas before attempting early cone collections. Nevertheless, GDD monitoring can provide a 4-5 week extension in the cone collection season for black spruce in many areas of central Newfoundland.

White spruce seed from cones collected before 1100 GDD showed reduced seed yield and quality. White spruce releases most of its seed within several weeks of natural cone ripening, leaving only a very short time of about 100 GDD for cone collection prior to natural cone ripening. In most areas of central Newfoundland, this will normally allow for a maximum period of 2 weeks prior to the beginning of natural seed release, depending on the rate of GDD accumulations later in the season (Appendix 1).

To summarize, growing degree-day accumulations may provide a useful, easily obtained, physical index for monitoring stages of seed maturation in trees, thus allowing operational cone collections to take full advantage of the cone collection season. The necessary information can be obtained from the nearest weather station, and the index can be computed with calculations based on the simple mean of the maximum and minimum daily temperatures. A map showing the locations of Atmospheric Environment Services (Environment Canada) weather stations appears in Figure 2, together with the forest administrative units of Newfoundland's Department of Forestry and Agriculture. The distribution of these weather stations appears sufficient for the purposes of monitoring seasonal accumulations of GDD and could be used by forestry personnel to monitor cone ripening in all commercially important native conifers. A list of telephone numbers are presented in Appendix 2 to assist those monitoring seasonal GDD accumulations for planning operational cone collections.

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Appendix 1

Growing degree-day (GDD) accumulations at 5 day intervals at sites in Newfoundland from 1976 to 1990.

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
Argentia	Aug. 10	11	579 ± 74	496 - 730	12.8
	Aug. 15	11	631 ± 73	551 - 772	11.6
	Aug. 20	11	681 ± 76	594 - 825	11.2
	Aug. 25	11	730 ± 76	640 - 871	10.4
	Aug. 30	11	777 ± 74	680 - 910	9.5
	Sept. 5	11	830 ± 75	727 - 954	9.1
	Sept. 10	11	871 ± 76	771 - 1000	8.7
	Sept. 15	11	910 ± 75	812 - 1037	8.2
	Sept. 20	11	946 ± 76	839 - 1070	8.0
Baie Verte	Aug. 10	13	708 ± 99	544 - 872	13.9
	Aug. 15	13	759 ± 102	585 - 914	13.4
	Aug. 20	13	804 ± 108	620 - 966	13.4
	Aug. 25	13	843 ± 109	645 - 1003	12.9
	Aug. 30	13	888 ± 114	666 - 1041	12.8
	Sept. 5	13	931 ± 114	706 - 1091	12.3
	Sept. 10	13	965 ± 125	711 - 1158	12.9
	Sept. 15	13	994 ± 129	719 - 1191	13.0
	Sept. 20	13	1019 ± 133	741 - 1225	13.0
Bay d'Espoir	Aug. 10	14	812 ± 68	686 - 933	8.4
	Aug. 15	14	871 ± 67	754 - 979	7.6
	Aug. 20	14	926 ± 70	801 - 104	7.5
	Aug. 25	14	975 ± 69	854 - 1082	7.1
	Aug. 30	14	1022 ± 71	893 - 1141	7.0

Appendix 1. (Cont'd.)

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
	Sept. 5	14	1075 ± 74	946 - 1203	6.9
	Sept. 10	14	1115 ± 80	983 - 1247	7.2
	Sept. 15	14	1151 ± 84	1013 - 1281	7.3
	Sept. 20	14	1181 ± 85	1040 - 1312	7.2
Bonavista	Aug. 10	14	652 ± 78	488 - 7655	12.0
	Aug. 15	14	705 ± 78	558 - 827	11.1
	Aug. 20	14	755 ± 83	592 - 892	11.0
	Aug. 25	14	799 ± 85	620 - 945	10.6
	Aug. 30	14	845 ± 88	648 - 986	10.4
	Sept. 5	14	893 ± 88	700 - 1043	9.8
	Sept. 10	14	931 ± 92	740 - 1103	9.9
	Sept. 15	14	966 ± 95	774 - 1149	9.8
	Sept. 20	14	998 ± 98	795 - 1185	9.8
Burgeo	Aug. 10	14	553 ± 48	490 - 620	8.6
	Aug. 15	14	604 ± 49	540 - 677	8.2
	Aug. 20	14	653 ± 53	583 - 731	8.1
	Aug. 25	14	700 ± 53	629 - 777	7.6
	Aug. 30	14	743 ± 51	672 - 825	6.9
	Sept. 5	14	792 ± 54	714 - 883	6.9
	Sept. 10	14	830 ± 58	746 - 926	6.9
	Sept. 15	14	863 ± 62	774 - 967	7.2
	Sept. 20	14	893 ± 63	802 - 995	7.0
Comfort Cove	Aug. 10	14	793 ± 85	614 - 959	10.8
	Aug. 15	14	847 ± 86	682 - 1008	10.1
	Aug. 20	14	896 ± 88	720 - 1052	9.8

Appendix 1. (Cont'd.)

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
	Aug. 25	14	939 ± 88	842 - 1189	9.4
	Aug. 30	14	984 ± 91	786 - 1148	9.3
	Sept. 5	14	1030 ± 88	842 - 1189	8.5
	Sept. 10	14	1066 ± 93	878 - 1227	8.7
	Sept. 15	14	1096 ± 95	906 -1261	8.7
	Sept. 20	14	1122 ± 98	926 -1300	8.7
Cormack	Aug. 10	8	753 ± 56	673 - 837	7.4
	Aug. 15	8	806 ± 58	719 - 899	7.2
	Aug. 20	8	856 ± 60	777 - 954	7.0
	Aug. 25	8	894 ± 59	821 - 992	6.6
	Aug. 30	8	935 ± 54	865 - 1021	5.8
	Sept. 5	8	980 ± 60	896 - 1065	6.1
	Sept. 10	8	1016 ± 65	937 - 1112	6.4
	Sept. 15	8	1044 ± 70	961 - 1148	6.7
	Sept. 20	8	1067 ± 74	973 - 1176	6.8
Corner Brook	Aug. 10	14	913 ± 95	754 - 1074	10.4
	Aug. 15	14	976 ± 96	806 - 1125	9.8
	Aug. 20	14	1034 ± 99	846 - 1203	9.6
	Aug. 25	14	1087 ± 98	902 - 1258	9.1
	Aug.30	14	1139 ± 100	949 - 1294	8.7
	Sept. 5	14	1197 ± 102	1009 - 1356	8.5
	Sept. 10	14	1241 ± 108	1048 - 1417	8.7
	Sept. 15	14	1279 ± 110	1081 - 1461	8.6
	Sept. 20	14	1313 ± 114	1103 - 1496	8.6
Botwood	Aug. 10	14	897 ± 86	728 - 1035	9.6

Appendix 1. (Cont'd.)

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
	Aug. 15	14	958 ± 86	783 - 1093	9.0
	Aug. 20	14	1013 ± 90	813 - 1162	8.8
	Aug. 25	14	1062 ± 89	856 - 1207	8.4
	Aug. 30	14	1113 ± 91	895 - 1248	8.2
	Sept. 5	14	1166 ± 90	956 - 1302	7.7
	Sept. 10	14	1207 ± 95	995 - 1363	7.9
	Sept. 15	14	1242 ± 97	1030 - 1404	7.8
	Sept. 20	14	1274 ± 99	1056 - 1441	7.8
Buchans	Aug. 10	14	790 ± 85	644 - 945	10.8
	Aug. 15	14	846 ± 85	698 - 987	10.1
	Aug. 20	14	896 ± 87	732 - 1044	9.7
	Aug. 25	14	942 ± 87	779 - 1087	9.2
	Aug. 30	14	987 ± 86	820 - 1128	8.8
	Sept. 5	14	1034 ± 85	871 - 1174	8.2
	Sept. 10	14	1070 ± 91	904 - 1219	8.5
	Sept. 15	14	1100 ± 92	932 - 1256	8.4
	Sept. 20	14	1127 ± 96	952 - 1289	8.5
Daniel's Harbour	Aug. 10	13	604 ± 76	511 - 727	12.6
	Aug. 15	13	1067 ± 74	973 - 1176	11.3
	Aug. 20	13	1067 ± 74	973 - 1176	11.0
	Aug. 25	13	1067 ± 74	973 -1176	10.2
	Aug. 30	13	1067 ± 74	973 - 1176	9.6
	Sept. 5	13	1067 ± 74	973 - 1176	9.2
	Sept. 10	13	1067 ± 74	973 -1176	9.5
	Sept. 15	13	892 ± 84	763 - 1176	9.4

Appendix 1. (Cont'd.)

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
	Sept. 20	13	918 ± 88	780 - 1063	9.5
Deer Lake	Aug. 10	14	819 ± 84	681 - 1010	10.3
	Aug. 15	14	876 ± 83	751 - 1058	9.5
	Aug. 20	14	928 ± 84	792 - 1101	9.1
	Aug. 25	14	976 ± 84	850 - 1153	8.6
	Aug. 30	14	1024 ± 84	894 - 1209	8.2
	Sept. 5	14	1076 ± 86	940 - 1267	8.0
	Sept. 10	14	1113 ± 92	966 - 1311	8.3
	Sept. 15	14	1146 ± 94	1008 - 1348	8.3
	Sept. 20	14	1175 ± 99	1037 - 1384	8.4
Exploit's Dam	Aug. 10	14	735 ± 85	584 - 896	11.6
	Aug. 15	14	787 ± 85	648 - 938	10.8
	Aug. 20	14	835 ± 88	698 - 999	10.5
	Aug. 25	14	879 ± 88	741 - 1045	10.1
	Aug. 30	14	920 ± 88	778 - 1077	9.6
	Sept. 5	14	995 ± 91	821 - 1131	9.4
	Sept. 10	14	998 ± 96	845 - 1170	9.6
	Sept. 15	14	1027 ± 99	879 - 1206	9.6
	Sept. 20	14	1050 ± 102	901 - 1234	9.8
Flowers Cove	Aug. 10	14	461 ± 75	353 - 651	16.2
	Aug. 15	14	500 ± 76	401 - 692	15.2
	Aug. 20	14	535 ± 78	432 - 731	14.6
	Aug. 25	14	571 ± 83	458 - 769	14.6
	Aug. 30	14	605 ± 91	471 - 808	15.0
	Sept. 5	14	641 ± 98	471 - 851	15.2

Appendix 1. (Cont'd.)

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
	Sept. 10	14	668 ± 103	471 - 881	15.4
	Sept. 15	14	691 ± 104	495 - 907	15.0
	Sept. 20	14	711 ± 102	527 - 931	14.4
Gander Int'l Airport	Aug. 10	14	796 ± 84	630 - 954	10.6
	Aug. 15	14	851 ± 84	691 - 1001	9.9
	Aug. 20	14	902 ± 88	715 - 1048	9.8
	Aug. 25	14	946 ± 88	751 - 1096	9.3
	Aug. 30	14	991 ± 91	784 - 1150	9.2
	Sept. 5	14	1039 ± 90	838 - 1194	8.6
	Sept. 10	14	1076 ± 95	876 - 1231	8.8
	Sept. 15	14	1107 ± 97	904 - 1269	8.8
	Sept. 20	14	1134 ± 100	926 - 100	8.8
Grand Falls	Aug. 10	14	922 ± 88	755 - 1085	9.5
	Aug. 15	14	983 ± 87	827 - 1139	8.8
	Aug. 20	14	1039 ± 89	862 - 1188	8.6
	Aug. 25	14	1089 ± 89	909 - 1241	8.2
	Aug. 30	14	1140 ± 90	952 - 1301	7.9
	Sept. 5	14	1194 ± 90	1015 - 1360	7.5
	Sept. 10	14	1234 ± 96	1054 - 1401	7.7
	Sept. 15	14	1267 ± 98	1088 - 1439	7.7
	Sept. 20	14	1299 ± 103	1114 - 1488	7.9
Holyrood	Aug. 10	13	779 ± 170	288 - 902	21.8
	Aug. 15	13	840 ± 168	364 - 975	20.0
	Aug. 20	13	898 ± 167	436 - 1036	18.6
	Aug. 25	13	951 ± 167	497 - 1101	17.6

Appendix 1. (Cont'd.)

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
	Aug. 30	13	1003 ± 171	544 - 1166	17.1
	Sept. 5	13	1057 ± 170	604 - 1220	16.0
	Sept. 10	13	1101 ± 170	653 - 1217	15.4
	Sept. 15	13	1142 ± 167	710 - 1315	14.6
	Sept. 20	13	1178 ± 167	748 - 1355	14.1
Lethbridge	Aug. 10	9	779 ± 108	578 - 903	13.9
	Aug. 15	9	839 ± 103	645 - 951	12.3
	Aug. 20	9	897 ± 98	716 - 1005	10.9
	Aug. 25	9	943 ± 93	769 - 1046	9.9
	Aug. 30	9	987 ± 97	805 - 1076	9.8
	Sept. 5	9	1033 ± 95	854 - 1128	9.2
	Sept. 10	9	1073 ± 95	908 - 1174	8.9
	Sept. 15	9	1110 ± 92	956 - 1210	8.3
	Sept. 20	9	1137 ± 90	983 - 1237	7.9
Norris Arm	Aug. 10	14	936 ± 86	758 - 1062	9.2
	Aug. 15	14	997 ± 86	825 - 1118	8.6
	Aug. 20	14	1054 ± 89	854 - 1189	8.4
	Aug. 25	14	1103 ± 89	897 - 1238	8.0
	Aug. 30	14	1153 ± 92	936 - 1278	7.9
	Sept. 5	14	1207 ± 90	997 - 1336	7.5
	Sept. 10	14	1248 ± 98	1038 - 1398	7.8
	Sept. 15	14	1285 ± 100	1072 - 1439	7.8
	Sept. 20	14	1315 ± 104	1097 -1476	7.9
Port aux Basques	Aug. 10	14	552 ± 47	473 - 622	8.6
	Aug. 15	14	604 ± 52	520 - 688	8.6

Appendix 1. (Cont'd.)

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
	Aug. 20	14	654 ± 57	561 - 752	8.7
	Aug. 25	14	702 ± 58	611 - 806	8.2
	Aug. 30	14	747 ± 58	656 - 864	7.7
	Sept. 5	14	797 ± 60	692 - 923	7.5
	Sept. 10	14	837 ± 64	728 - 970	7.6
	Sept. 15	14	870 ± 68	756 - 1011	7.8
	Sept. 20	14	901 ± 70	781 - 1042	7.8
Plum Point	Aug. 10	14	576 ± 69	454 - 694	12.0
	Aug. 15	14	622 ± 70	479 - 737	11.3
	Aug. 20	14	665 ± 72	504 - 772	10.8
	Aug. 25	14	706 ± 73	534 - 815	10.3
	Aug. 30	14	748 ± 74	564 - 858	9.9
	Sept. 5	14	792 ± 74	609 - 898	9.4
	Sept. 10	14	825 ± 77	641 - 926	9.3
	Sept. 15	14	851 ± 76	660 - 953	9.0
	Sept. 20	14	875 ± 79	689 - 985	9.0
Port Saunders	Aug. 10	10	603 ± 103	460 - 798	17.1
	Aug. 15	10	650 ± 103	495 - 842	15.9
	Aug. 20	10	692 ± 106	520 - 877	15.3
	Aug. 25	10	731 ± 106	554 - 912	14.4
	Aug. 30	10	769 ± 106	585 - 947	13.7
	Sept. 5	10	810 ± 109	630 - 1000	13.4
	Sept. 10	10	843 ± 113	661 - 1045	13.4
	Sept. 15	10	869 ± 114	688 - 1076	13.1
	Sept. 20	10	889 ± 115	709 - 1098	12.9

Appendix 1. (Cont'd.)

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
Rocky Harbour	Aug. 10	14	737 ± 93	573 - 890	12.7
	Aug. 15	14	790 ± 94	628 - 933	11.9
	Aug. 20	14	841 ± 98	688 - 989	11.6
	Aug. 25	14	886 ± 98	733 - 1038	11.1
	Aug. 30	14	932 ± 101	769 - 1076	10.8
	Sept. 5	14	979 ± 104	817 - 1127	10.7
	Sept. 10	14	1014 ± 114	843 - 1180	11.3
	Sept. 15	14	1044 ± 117	882 - 1223	11.2
	Sept. 20	14	1072 ± 122	893 - 1254	11.4
Salmonier (Nature Pk.)	Aug. 10	11	713 ± 77	566 - 841	10.7
	Aug. 15	11	767 ± 76	623 - 894	9.9
	Aug. 20	11	816 ± 75	680 - 945	9.2
	Aug. 25	11	860 ± 74	728 - 1002	8.6
	Aug. 30	11	900 ± 78	771 - 1055	8.7
	Sept. 5	11	941 ± 82	828 - 1116	8.7
	Sept. 10	11	974 ± 84	862 - 1158	8.6
	Sept. 15	11	1998 ± 80	909 - 1190	8.0
	Sept. 20	11	1037 ± 83	941 - 1232	8.0
St. John's Airport	Aug. 10	14	722 ± 80	546 - 815	11.1
	Aug. 15	14	775 ± 80	616 - 872	10.3
	Aug. 20	14	825 ± 87	664 - 944	10.5
	Aug. 25	14	870 ± 87	707 - 1002	10.0
	Aug. 30	14	914 ± 91	736 - 1057	9.9
	Sept. 5	14	959 ± 90	783 - 1105	9.4
	Sept. 10	14	996 ± 96	825 - 1154	9.6

Appendix 1. (Cont'd.)

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
	Sept. 15	14	1031 ± 98	860 - 1189	9.6
	Sept. 20	14	1062 ± 101	874 - 1225	9.5
St. John's (West)	Aug. 10	14	763 ± 83	572 - 872	10.8
	Aug. 15	14	818 ± 83	642 - 923	10.1
	Aug. 20	14	870 ± 88	704 - 973	10.1
	Aug. 25	14	919 ± 88	753 - 1033	9.6
	Aug. 30	14	964 ± 92	802 - 1091	9.5
	Sept. 5	14	1013 ± 91	858 - 1141	9.0
	Sept. 10	14	1052 ± 97	894 - 1192	9.2
	Sept. 15	14	1090 ± 99	938 - 1235	9.1
	Sept. 20	14	1121 ± 100	960 - 1268	9.0
Sop's Arm	Aug. 10	10	669 ± 126	478 - 870	18.9
	Aug. 15	10	719 ± 133	536 - 937	18.5
	Aug. 20	10	769 ± 136	574 - 1015	17.7
	Aug. 25	10	809 ± 142	594 - 1056	17.6
	Aug. 30	10	854 ± 147	620 - 1038	17.2
	Sept. 5	10	900 ± 156	647 - 1128	17.4
	Sept. 10	10	938 ± 165	669 - 1185	17.6
	Sept. 15	10	969 ± 171	680 - 1221	17.6
	Sept. 20	10	995 ± 178	701 - 1260	17.9
Springdale	Aug. 10	9	760 ± 84	602 - 893	11.0
	Aug. 15	9	815 ± 82	668 - 956	10.1
	Aug. 20	9	865 ± 82	730 - 1015	9.5
	Aug. 25	9	904 ± 82	769 - 1056	9.0
	Aug. 30	9	966 ± 81	804 - 1088	8.6

Appendix 1. (Cont'd.)

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
	Sept. 5	9	990 ± 85	849 - 1135	8.6
	Sept. 10	9	1027 ± 92	876 - 1191	9.0
	Sept. 15	9	1056 ± 95	918 - 1228	9.0
	Sept. 20	9	1079 ± 96	941 - 1259	8.9
Stephenville Airport	Aug. 10	14	813 ± 76	713 - 944	9.2
	Aug. 15	14	871 ± 75	774 - 996	8.6
	Aug. 20	14	928 ± 78	821 - 1052	8.4
	Aug. 25	14	978 ± 78	868 - 1107	7.9
	Aug. 30	14	1027 ± 78	913 - 1158	7.6
	Sept. 5	14	1081 ± 80	964 - 1211	7.4
	Sept. 10	14	1125 ± 86	1003 - 1256	7.7
	Sept. 15	14	1161 ± 90	1034 - 1302	7.8
	Sept. 20	14	1194 ± 93	1060 - 1339	7.8
Terra Nova Nat'l Park	Aug. 10	12	810 ± 105	504 - 540	15.4
	Aug. 15	12	868 ± 128	540 - 574	14.7
	Aug. 20	12	920 ± 140	578 - 578	15.2
	Aug. 25	12	967 ± 144	603 - 604	15.0
	Aug. 30	12	1012 ± 150	629 - 629	14.8
	Sept. 5	12	1062 ± 149	687 - 688	14.0
	Sept. 10	12	1104 ± 154	732 - 732	13.9
	Sept. 15	12	1142 ± 156	766 - 766	13.7
	Sept. 20	12	1174 ± 158	792 - 792	13.5
St. Anthony	Aug. 10	14	446 ± 60	364 - 578	13.4
	Aug. 15	14	486 ± 62	383 - 615	12.9
	Aug. 20	14	520 ± 62	407 - 646	12.0

Appendix 1. (Concl'd.)

Location	Date	No. of Years	GDD Mean ± S.D.	GDD Range	CV[1]
	Aug. 25	14	548 ± 60	428 - 675	11.0
	Aug. 30	14	582 ± 60	454 - 706	10.3
	Sept. 5	14	613 ± 58	492 - 732	9.5
	Sept. 10	14	636 ± 62	515 - 751	9.8
	Sept. 15	14	653 ± 61	534 - 765	9.4
	Sept. 20	14	668 ± 63	547 - 785	9.4

[1] Coefficient of variation

Appendix 2

Telephone numbers of main Newfoundland weather centres for inquiries regarding daily maximum and minimum temperatures for growing degree-day calculations: (i) Comfort Cove (Lewisporte), (709) 261-2323; (ii) Deer Lake Airport, (709) 635-2848, (iii) Gander International Airport, (709) 256-6609; (iv) St. John's Airport, (709) 772-5532; and (v) Stephenville Airport, (709) 643-3600.

Telephone number of the Atmospheric Environment Service (Environment Canada) for inquiries regarding historical weather data and growing degree-day calculations: (709) 772-4695.